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INTRODUCTION

For more than a decade, individual research groups at Goddard Space Flight Center and the University of Maryland have participated in experiments and observations which have led to the emergence of new disciplines. Having recognized at an early stage the critical importance of maintaining detector capabilities which utilize "state of the art" techniques, the two institutions formulated a joint program directed towards this end. This program has involved coordination of a broad range of efforts and activities including joint experiments, collaboration in theoretical studies, instrument design, calibrations, and data analysis. As part of the effort to provide a stimulating reseearch environment, a series of joint seminars on topics in Astrophysics and Space Physics has been instituted and is held regularly at the University. Many phases of the cooperative effort directly involve faculty, research associates and graduate students in the interpretation of data which is carried out at the Goddard Space Flight Center as well as on campus. Two aspects of this joint program are particularly important. The first is the close tie between scientists at Goddard and the faculty and graduate students at Maryland. This has resulted, for example, in Ph.D. thesis research for a number of graduate students and has been a vital part of the program. The second aspect has to do with the development of advanced instrumentation for space experiments and the cooperative analysis of data from such experiments.

Detailed information on the research projects is available in the annual proposals submitted for this grant. The following are summaries of progress made under this contract. A representative bibliography is also included.

SOLAR WIND AND INTERPLANETARY STUDIES

Using our sensor on ISEE-3 we reported the first measurements of Fe charge states in two coronal hole-associated high speed streams. Our measurements show that the solar wind emitted from coronal hole regions is characterized by lower charge states thatn is the solar wind emitted from the quiet corona. We have also been able to determine the charge states of Fe in a driver plasma which originated near a solar flare site and have found that this solar wind flow is characterized by much higher thatn normal charge states, implying that the solar flare effectively heated the solar atmosphere out to distances of several solar radii. We have also measured solar wind Fe and Si-S charge states in the postshock "sheath region" preceding the driver plasma.

Using the plasma composition experiment (CHEM) on the AMPTE CCE spacecraft we have extended solar wind composition measurements up to and including iron. Resulst obtained add support to the idea that solar energetic particles are accelerated out of coronal material.

Several upstream particle events were observed on several occasions when an unusually dense solar wind compressed the earth's magnetosphere allowing the AMPTE/CCE spacecraft to sample the magnetosheath and upstream region. Results obtained for various intensity ratios indicate that there is little, if any, magnetospheric contribution to the observed upstream particle population.

MAGNETOSPHERIC STUDIES

Eight event intervals from the January-June 1983 timeframe were chosen by the Coordinated Data Analysis Workshop (CDAW) 8 for the study of magnetotail dynamics and its relationship to substorm activity and the possible formation of plasmoids. Our study using the ULECA sensor on ISEE-3 enabled us to present typical energy spectra and relative abundance ratios for suprathermal H^+ and H^{+2} ions during these event time periods.

Using the CHEM spectrometer on the AMPTE/CCE spacecraft we have reported on the radial distribution of He^+ and He^{++} ions during both quiet and active magnetospheric conditions. The radial profiles vary with energy largely reflecting the energy dependence of the charge exchange cross sections. During storm times both species penetrate more deeply into the magnetosphere, consistent with convective flows at these energies. Other ions have also been studied and it has been determined that charge exchange processes altered the relative abundance of some species so that the observed ring current ions do not directly reflect the abundances of initially injected ions.

ACCELERATION AND PROPAGATION OF SOLAR ENERGETIC PARTICLES

It ahs been found that for ion events whose time-intensity profiles are characterized by very fast rise and decay times the major ion species H, He, O, and Fe all exhibit scatter-free behavior with differences that appear to be organized by particle energy and charge-to-mass ratio. Using a more realistic model including focused transport to study these events it has now been found that for sufficiently large interplanetary scattering mean free paths, fits can be obtained with pulses of width comparable to our observations, and with wakes whose decay is rapid enough to consistent with our observations.

FUTURE AREAS OF DEVELOPMENT

The Maryland experiments on several spacecraft have used improvements and refinements to the basic ion composition and charge states measurement method using a combination of electrostatic deflection in high voltage regions and total energy measurements with solid state detectors. Recently, new techniques have allowed the complete and simultaneous determination of all of the important ion parameters. Newer instrumentation to achieve comprehensive measurements of ionization state, mass, energy and arrival direction, combining electrostatic deflection and total energy measurement with a time-of-flight measurement has proven successful on the AMPTE/CCE CHEM experiment. The SWICS sensor for the ESA ULYSSES spacecraft is expected to be launched in 1990 and should result in significant advances in solar wind compositional and charge state studies.

Techniques are now being explored for the measurement of secondary electrons which are characteristically emitted when ions hit a target material. Development efforts in this area include the investigation of ultra-thin foils for very low energy threshold measurements, and the systematic study of electrostatic focusing techniques to achieve good efficiencies in the acceleration and focusing of secondary electrons towards curved microchannel plates that hve been found to be excellent detectors of secondary electrons.

The development of a position-sensing microchannel plate assembly of large area to increase the resolution of sensors similar to SWICS, or to have a greatly increased collecting power while maintaining a high resolution, is continuing.

Practical, low cost, low power consumption data processing units which have the effect of "compressing" data during relatively sophisticated on-board data processing, before it is transmitted to the ground, are being developed for future missions.

DETECTOR AND SENSOR RESPONSE STUDIES

The University fo Maryland is attempting to refurbish an accelerator facility for use in our laboratory. For many years we have studied the characteristics of the Time-of-Flight vs. energy telescope using heavy ion beams accelerated by the GSFC and MPAe Van de Graaf accelerators. These studies are continuing buth the availability of a multiple-species ion source in our laboratory would greatly facilitate the development of our future time-of-flight sensors.

HIGH ENERGY COSMIC RAYS

A Large Isotopic Composition Experiment (ALICE) is a balloon-borne instrument which measures the isotopic composition of cosmic rays over the energy and charge ranges 300-800 Mev/nucleon and neon through argon respectively. Recent cosmic ray experiments have detected neutron-rich isotope fluxes of neon and magnesium that exceed solar abundances by factors of up to three. Measurements of other, intermediate mass nuclei should help clarify the situation.

Final integration and calibration of the ALICE instrument was performed during April to June, 1987. The instrument was shipped to the

NSBF remote launch facility in Prince Albert, Canada, on July 1, 1987. The instrument was prepared for flight readiness during July and then successfully flown on August, 15, 1987. University fo Maryland graduate student, J.A. Esposito, was involved in all aspects of the integration, calibration and subsequent flight of ALICE.

The cosmic ray flux of antiprotons, particularly the low energy part of the spectrum, is of great significance for both astrophysics and cosmology.Past measurements of the flux of antiprotons at low energies is in disagreement with expectations from the best current theory. In an effort to check these measurements, the Low Energy Antiproton (LEAP) experiment was performed. Final integration and calibration of LEAP was performed during April to June, 1987. The instrument was shipped to Prince Albert, Canada, and prepared for flight readiness during July and August. LEAP was successfully flown on August 27, 1987. University of Maryland graduate student, S. Stochaj, was involved in all aspects of the integration, calibration and subsequent flight of LEAP.

Antiprotons are produced by cosmic rays which are incident on the upper atmosphere. Since balloon-borne experiments are carried out at residual atmospheric depths of 5 gm/cm^2, it is important to determine the background flux of atmospheric antiprotons. University of Maryland postdoctorate, J. Cole, has calculated the flux of antiprotons due to the reaction pp - pppp initiated by the spectrum of proton primaries incident on the upper layer of atmosphere. Both the downward flux and the atmospheric albedo of antiprotons have been determined as a funtion of antiproton energy and outgoing angle. This has been done for a flat atmosphere and calculations are in progress for a spherical exponential atmosphere.

LOW ENERGY COSMIC RAYS

The large-scale structure of the most energetic interplanetary shocks has been determined. the deduced magnetic field topolosy and it's implication for paticle acceleration, has permitted an explanation of the observed variation of intensity-time profiles of solar proton events as a function of the angle between the associated solar event and the observer.

Efforts are continuing in trying to define the phenomena associated with, and the energetic particle populations generated by, different modes of particle acceleration in the solar corona. A more extensive list of impulsive events is being generated in orderto better determine the relationship between the observed particle fluxes and the flare characteristics. This list will originate with electron observations and then the events will be examined in terms of other species such as He, O and Fe.

SOLAR MODULATION OF GALACTIC COSMIC RAYS

Work by Len Burlaga has shown a direct correlation between interplanetary magnetic field strength and the high-energy, galactic cosmic-ray count rate, both measured by the Voyager spacecraft. Perko & Burlaga [1987] demonstrated a formal relationship between these two quantities using the standard solar modulation equation, but only during cosmic-ray recovery from solar-cycle maximum. Current efforts are under way (with increasing success) to simulate the entire 8-10 year cosmic-ray cycle as measured by the Voyagers, showing it to be almost totally dominated by traveling regions of magnetic-field compressions.

LOW ENERGY GAMMA-RAY ASTRONOMY

Research using high resolution gamma-ray spectroscopy of celestial sources in the 20 keV to 20 MeV energy range to search for and study narrow lines in the low-energy gamma-ray spectrum continues.

The Gamma-Ray Imaging Spectrometer (GRIS) is nearly completed. Since the timely explosion of the Supernova 1987a in the Large Megallanic Cloud, the work effort on GRIS has accelerated to allow for the balloon-borne ovservations of the supernova from Australia in the spring and summer of 1988. Theis is the optimum time for observing the maximum gamma-ray flux from the supernova.

The Transient Gamma-Ray Spectrometer (TGRS) is a satellite-borne instrument to perform high resolution studies of the spectra of gamma-ray bursts. It will make spectral measurements of typically 40 times better energy resolution thatn the best previous instrument. It is planned for flight on the WIND spacecraft, part of the Global Geoscience System (GGS) mission to be launched in the early 1990's.

The search for the optical counterpart flash to gamma-ray bursts is being investigated with the Rapidly Moving Telescope (RMT) instrument. The RMT will have the capability to slew to any location on the night sky, track and image that location with 1 arcsecond resolution with 1 sec timing resolution. This project is in its major effort phase to complete the trial integration at the Goddard Optical Research Facility and final installation at the Kitt Peak National Observatory.

THEORETICAL ASTROPHYSICS

A program in cosmic ray astrophysics placing particular emphasis on the physics and radiation mechanisms in compact sources both on stellar and galactic scales, such as pulsars and active galactic nuclei, is being pursued.

Research in high energy radiation from pulsars and gamma-ray bursts with particular emphasis on processes in superstrong magnetic fields is being conducted, as is the modelling of the emission of similar radiation from active galactic nuclei.

Other research pertaining to cosmology and the interplay between cosmolosy and particle physics is being performed, as is solar flare research emphasizing gamma-ray line and neutron production in these events. Research on other topics continues as well.

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